Table L.8.1 : Results of DL-EPR Tests

Specimen		% Degree of sensitization (DOS)	
		Top surface	Bottom surface
Medium C type 304 SS	Untreated HAZ	0.45	0.26
	Laser treated HAZ	0.0123	-
High C type 304 SS	Untreated HAZ	12.38	42
	Laser treated HAZ	0.031	0.029

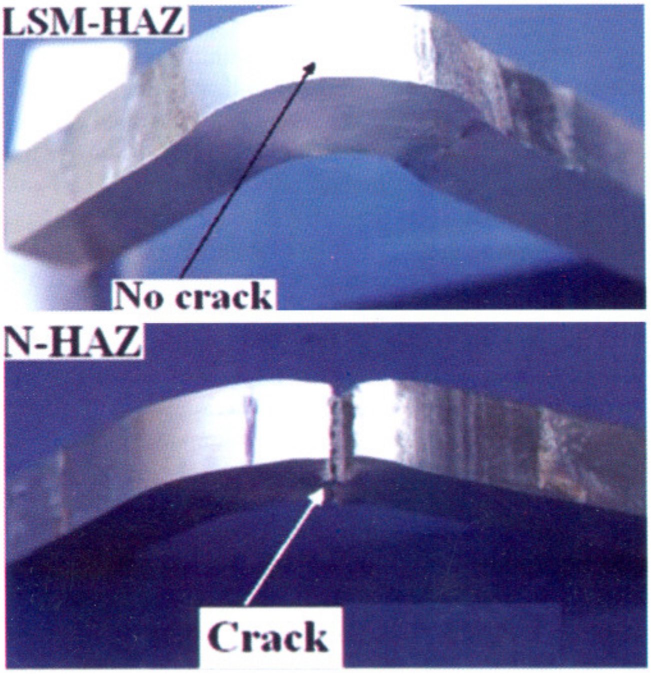

Fig. L.8.1: Comparison of untreated HAZ (N-HAZ) and pre-weld laser treated HAZ (LSM-HAZ) specimens of type 304 stainless steel after undergoing IGC test - ASTM A262 Practice E.

The pre-welding laser surface treatment technique has a strong potential in enhancing life of austenitic stainless steel welded components operating in corrosive environment, especially prevalent in process industry. This study has been performed in collaboration with Corrosion Science & Technology Division of Indira Gandhi Centre for Atomic Research, Kalpakkam.

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L.9: Dependence of the high order harmonic intensity on the length of the plasma plume

High order harmonic generation from the interaction of ultra-short laser pulses with a gaseous medium is an attractive method of generating ultra-short coherent XUV radiation. It is desirable to have high intensity of the harmonics for their deployment in practical applications. In this regard, the use of weakly ionized under-dense plasma plume as the medium for harmonic conversion has an interesting possibility of resonant intensity enhancement of particular harmonic orders. One may also achieve high harmonic intensity by increasing the medium length. However, phase mismatch between the laser field and the harmonic radiation due to medium dispersion accumulated during propagation over large medium length may limit the growth of harmonic intensity. Laser Plasma Division of RRCAT has carried out an experimental study on the variation of harmonic intensity with medium length in low ionized laser produced plasma plumes.

The laser used in the study was a 10 Hz Ti:sapphire laser ($\lambda = 790$ nm). A part of the uncompressed laser pre-pulse of duration ~300 ps was line focussed by two crossed cylindrical lenses on a planar silver strip of 2 mm width, to a focal-spot size of 2 mm x300 μm. After a delay of 60 ns, the main laser pulse ($\tau \sim 45$ fs) was focussed in the plasma plume, with the beam propagating parallel to target surface. The peak laser intensity of the fs pulse at the centre of the plasma plume was ~2.5 10^{15} W/cm^2. To study the effect of medium length on harmonic emission, the length of the plasma plume was varied (in the range of 0.8 mm to 2 mm) by inserting a slit of variable width in the centre of the pre-pulse beam before the lens assembly. The high-order harmonics were analyzed by an in-house developed flat-field grazing-incidence spectrograph, and were detected by an MCP-CCD camera combination. The odd harmonics up to 47th harmonic order were observed.

The variation of the 21st, 33rd and 41st harmonic intensity with plasma plume length is shown in Fig.L.9.1. It is seen from the figure that the intensity of harmonics (I_H) increases with the medium length (L_{med}) as I_H (L_{med})ß, where the scaling exponent ß is ~ 0.9, 0.8, and 0.7 for 21st, 33rd, and 41st harmonics respectively. Next, the variation of harmonic intensity with harmonic order for two different plume lengths is shown in Fig.L.9.2. It is seen from this figure that the harmonic intensity decreases with increasing harmonic order, which is in variance with the plateau-like behaviour observed in gaseous media.

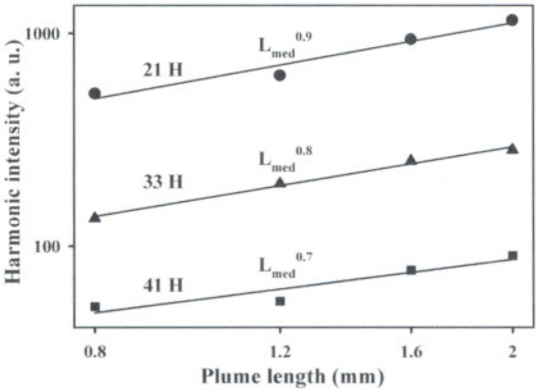

Fig. L.9.1: Variation of the harmonic intensity with the plasma plume length

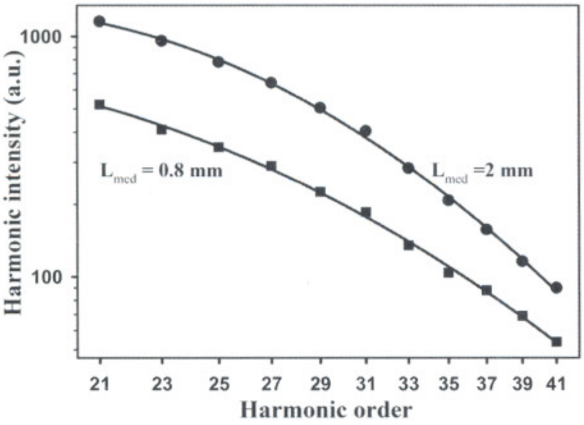

Fig. L.9.2 : Harmonic intensity variation with the harmonic order, for two lengths of the plasma plume.

The above results have been explained from the propagation of harmonic radiation in dispersive and absorptive media. As the laser beam propagates through the medium and produces harmonics, phase mismatch (Δk) between the laser pulse and harmonic radiation may increase with length. There are mainly four factors that contribute to Δk: 1) atomic dispersion, 2) plasma dispersion, 3) Gouy phase shift, and 4) intensity dependent dynamical phase shift in nonlinear dipole moments. Using these, the scaling of harmonic intensity with medium length was calculated. The intensity scaling exponent ß was observed to be ~1.1, 0.9 and 0.8 for 21st, 33rd and 41st harmonic orders respectively. These values are quite close to those observed experimentally. [For more details, please see *H. Singhal et al, Phy. Rev. A*, ***79****, 023807, 2009*]

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L.10: Development of high power diode-side-pumped CW Nd:YAG laser

A high-power, diode-pumped CW Nd:YAG laser, using copper-coated optically pumped cavity generating 1210 W of output power, has been developed in the Solid State Laser Division of RRCAT. For this laser, the diode pump power was 2400 W, which corresponds to an optical slope efficiency of 55% and an optical conversion efficiency of 50%. These efficiencies and power are the highest reported to the best of our knowledge using a single ϕ 6mm x 150 mm Nd:YAG rod.

Figure L.10.1 shows a cross-sectional view of the pump cavity of the laser. There was a reflective coating over the flow tube to trap the pump light within the flow tube by multiple reflections, for efficient utilization of the pump radiation. Copper coating was used instead of gold coating for two reasons: a) copper has excellent adhesion on the glass substrate, b) it has higher reflectivity than gold around the diode emission wavelength of 808 nm. In order to avoid any oxidation of copper, a thin chromium layer was coated over copper layer. The laser pump head consisted of 0.6% doped Nd:YAG rod which was surrounded by a copper-coated quartz flow tube on the outside surface with three narrow windows of 1.5 mm width and 120 mm length, in three-fold angularly symmetric directions. Three linear diode modules were positioned 0.2 mm away from the periphery of the flow tube at angles of 120° with respect to each other, to pump the Nd:YAG rod over a length of 120 mm. With this configuration, the pump light gets directly coupled into the gain medium. Each module had ten 1-cm long diode laser bars. The maximum output power of each diode laser bar was 80 W. The diode laser bar had an in-built micro-channel cooled heat sink, requiring a minimum water flow of 300 ml per minute (lpm) for efficient heat removal. All the diodes were connected in series and were operated by a constant current, controlled power source. Chilled de-ionized water was used as the coolant for both, the diode and the laser rod. The calculated Reynolds number and the heat transfer coefficient are 17,700 and 3.3 W/cm^2-°C, respectively, for the measured flow rate of 11 lpm. The emission wavelength of the diode laser bar was maintained at the peak of the absorption band of Nd:YAG laser crystal near 808 nm, by adjusting the coolant temperature. Considering the thermo-mechanical properties of Nd:YAG crystal, theoretically allowed maximum heat dissipation (i.e fracture limit) is 200 W/cm. The actual maximum pump power line density was 240 W/cm. Assuming that 40% of the pump power is dissipated as heat (under no lasing condition) in the laser rod, the laser can be considered to be